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S12CIS

1. Your reference — S12CIS

2. Patent application number *(The Patent Office will fill this part in)* — 0326916.4

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Dr DAN MERRITT

139 BAGINTON ROAD, COVENTRY, CV3 6FY , U.K.

Patents ADP number *(if you know it)* — 5523360002

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — INTERNAL COMBUSTION ENGINE

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — ~~APPLICANT'S ADDRESS~~

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
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8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — NO

Answer YES if:

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Continuation sheets of this form	
Description	11
Claim(s)	2
Abstract	1
Drawing(s)	5 &5

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	/
Request for a preliminary examination and search (Patents Form 9/77)	one
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	

11. I/~~We~~ request the grant of a patent on the basis of this application.

Signature(s) D. Merritt D. Merritt Date 17 NOVEMBER 2003

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

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INTERNAL COMBUSTION ENGINE

This invention relates to spark ignited reciprocating internal combustion engines.

In particular it relates to lean-burn reciprocating engines, capable of operating at part load without using a throttle valve. It uses fuel injection into an indirect combustion chamber. The invention can be applied to both four stroke and two stroke engine cycles and is suitable for use in automotive applications with gasoline fuel.

Some internal combustion engines can be classified as spark ignited lean-burn engines. Reciprocating piston engines of this type can operate with lean overall air fuel ratios at part load. The air fuel ratio calculated overall is larger than chemically correct, (the stoichiometric ratio), and if it were allowed to mix fuel and air to form a homogeneous mixture overall it would be difficult or impossible to ignite it by a spark. To operate successfully such engines avoid a homogeneous mixture at part load by deliberately stratifying air fuel mixtures into richer and leaner zones. Various methods are used to ensure that the spark plug is located in a position where some of the air fuel mixture allows spark ignition to be effective.

Lean-burn engines can achieve an improved thermal efficiency at part loads by avoiding the need to throttle the air intake and also by reducing heat loss soon after the combustion process since the products of combustion are cooled when mixed with excess air.

Some methods used so far to promote lean-burn in spark ignition reciprocating engines are not wholly satisfactory.

This invention seeks to provide an improved lean-burn internal combustion engine with a potential to promote reliable spark ignition and stable combustion. Accordingly, this invention provides an internal combustion engine comprising:

a piston reciprocating in a cylinder;

air inlet means communicating with the cylinder;

exhaust means communicating with the cylinder;

an indirect combustion chamber communicating with the cylinder comprising a near end and a far end in relation to the piston;

transfer orifice means communicating with the cylinder and the combustion chamber at its near end;

spark ignition means communicating with the combustion chamber;

fuel injection means communicating with the combustion chamber;

management means to control the fuel injection process and spark ignition event;

Characterised in that the transfer orifice means is adapted to deliver a jet of air into the combustion chamber during the compression stroke of the piston forcing gas movement around the periphery of the combustion chamber in helical swirl motion in the axial direction away from the near end and in that the fuel injection means delivers fuel into the said jet of air to enable a spark ignitable mixture to form in the gas arriving at the spark ignition means.

Preferably the spark ignition means is a spark plug situated at or near the far end of the combustion chamber the end furthest from the piston and the transfer orifice means;

Preferably the fuel injection means communicating with the combustion chamber points a spray of fuel directly into the jet of airflow emerging from the transfer orifice means into the combustion chamber during the compression stroke and the fuel spray cone is chosen to allow all the fuel to be absorbed within the said air jet.

Preferably the management means provides control of the quantity and of the timing of fuel delivery to take place during the compression stroke of the piston and when necessary ensures the delivery of fuel quantity by controlling both the duration of injection and/or the pressure of the fuel supply to the fuel injection means.

The aim of the invention is to utilise the capability of air flow in a concentrated form of a jet moving at an appreciable velocity to rapidly and effectively vaporise liquid fuel spray injected into it to form an ignitable mixture and subsequently to direct this jet to generate helical swirl motion around the periphery of the combustion chamber. To use this helical swirl motion to stratify the mixture near the spark ignition means from air without fuel, which may follow. The stratifying process starts by first transporting the mixture after it is formed to the location of the spark ignition means for subsequent ignition. After arriving at the spark ignition means the spark ignitable mixture is perceived to continue in planar rotational motion about the axis of the combustion chamber and to remain in the vicinity of the spark plug and ignite when the spark appears irrespective of the composition of the gas upstream which may not be capable of ignition by spark.

It has been observed, in an experiment, that helical swirl flow can be easily produced by directing a jet of compressed air delivered from a nozzle, onto the internal wall of a vertical glass cylinder closed at its upper end. The nozzle is positioned at the lower, open end, against the inside of the glass wall at an angle to the axis of the cylinder to give a tangential velocity component around the periphery, for example forty-five degrees. Fine powder made of solid particles, for example talcum powder, is placed inside the glass cylinder before it is inverted, and if the inversion takes place after the air flow had started the fine powder does not fall down but remains rotating around the periphery at the top of the cylinder, as a ring, for as long as the air jet induced helical swirl flow is maintained. When the airflow is stopped the powder motion also stops and it drops downwards by gravity falling out of the cylinder. This phenomenon is applied in this invention, to air containing fuel vapour and possibly some fine fuel droplets, in the recognition of its ability to stratify spark ignitable mixture formed within the jet and to confine it in rotation at the location of a spark plug.

The term air is used herein to describe air which is either pure or contains other gases such as products of combustion, (which may be recirculated into the cylinder during the

induction stroke), or even hydrocarbon gases. The term mixture describes air mixed with vaporised fuel destined for combustion.

Preferably, at the end of the compression stroke the combustion chamber contains as much as possible of the mass of air trapped in the cylinder at the end of the induction stroke, consistent with practical constraints.

Preferably the combustion chamber is predominantly symmetrical about its longitudinal axis. This axis need not be parallel with the axis of the engine's cylinder. Inclination can be used to avoid a shallow entry angle for the transfer orifice means as it enters into the cylinder.

In order to minimise fluid friction losses during gas transfers through the transfer orifice means, the size of this orifice is preferably maximised, consistent with the need to promote a jet of air with suitable velocities flowing into the combustion chamber during the compression stroke.

This invention is further described hereinafter by the way of examples, with reference to the accompanying schematic drawings which are not to scale and are presented for illustration purposes only;

Figure 1 is a sectional elevation through a preferred form of internal combustion engine according to this invention with the piston at the beginning of compression stroke.

Figure 2 is a partial sectional elevation similar to Figure 1 but with the piston at mid compression stroke position and with a streamline superimposed to illustrate, in a simplified way, the meaning of helical swirl air motion in the combustion chamber.

Figure 3 is a partial sectional elevation through an embodiment of the combustion chamber illustrating, in a simplified way, with the aid of stream tube configuration, air and fuel movement and stratification during the compression stroke.

Figure 4 illustrates a combustion chamber inclined to the axis of the engine's cylinder with details of access for the fuel injection means and transfer orifice means.

Figure 5 illustrates a sectional view along line A-A of Figure 3 of a similar combustion chamber.

Figures 6a to 6f illustrate some shapes suitable for combustion chambers according to this invention.

Referring to the drawings by way of examples, Figure 1 shows the piston 1 with typical piston rings, cylinder 2 having axis of symmetry 18, air inlet means in the form of an inlet valve 3, exhaust means in the form of valve 4, flame plate 5, and indirect combustion chamber 6 communicating with cylinder 2 through transfer orifice means 7 situated at the near end 8 being the wall of the combustion chamber 6 nearest the piston, spark ignition means 9 situated at the far end 10 being at the end of the combustion chamber furthest from the piston, a fuel injection means 11 aligned with the orientation of the transfer orifice means and controlled by management means 12, to determine the fuel flow through fuel line 13.
In Figure 1 the transfer orifice means 7 and fuel injection means 11 are shown in dotted lines where they are situated behind the cross sectional view of the combustion chamber containing the chamber's axis of symmetry 19. These geometries are designed to impart helical swirl motion to the air after entry. Figures 4 and 5 further illustrate such a suitable geometry. Other schematic diagrams omit these details for the sake of simplicity of presentation.

The combustion chamber illustrated in this embodiment is shaped as a cylinder with a hemispherical near end 8 and a conical far end 10 but many shapes are possible, some are illustrated in Figure 6.

The spark ignition means 9 is shown as a typical spark plug situated at a generalised location on the conically shaped far end.

The fuel injector's 11 axis 21 is shown approximately coincident with the axis 20 of the transfer orifice means 7. This is a preferred feature to promote maximum entrainment of fuel into the air jet passing through orifice 7 but other directions inclined to this axis may also be suitable.

Figure 2 illustrates air motion in the combustion chamber during the compression stroke by way of an imaginary streamline shown for example. The air in cylinder 2 is forced into the combustion chamber 6 through the transfer orifice means 7 whose axis 20 is offset from the axis 19 of the combustion chamber and is inclined to it in a direction, which has a tangential component to the periphery 22 of the combustion chamber but is not shown in this diagram. This creates a jet of air, which meets the cylindrical wall of the combustion chamber at an oblique angle with tangential and axial velocity components, causing it to deflect tangentially and flow around the cylindrical wall of the combustion chamber and in a forward direction, like a screw thread, a motion termed helical swirl. This is illustrated by an imaginary streamline 14. When a streamline reaches the far end 10 it loses its axial velocity component. This causes a pressure rise downstream which decelerates the air following. The air reaching the far end 10 continues to swirl around the chamber wall and is pressed against the far end. Air that follows keeps pressing the swirling mass that entered earlier against the far end and adjacent to the spark plug 9. Streamlines generated when the air jet's velocity is highest, after the piston reaches its highest velocity during the compression stroke, will possess greater momentum and may penetrate or displace the earlier streamlines, which were generated when the air jet had lower velocities. The high momentum streamlines, which finally settle near the spark plug, should contain fuel and become a spark ignitable mixture because they are likely to become stratified and remain in position near the spark plug even after fuel delivery stops for later air streamlines. These stratified streamlines will burn even if the gas upstream is air without fuel.

Figure 3 illustrates, by way of an example, an imaginary stream tube 16 interacting with a fuel spray 17 emerging from injector 11 during the compression stroke. When this air fuel mixture arrives at the far end it swirls around the periphery forming a zone 15 of ignitable mixture in contact with the spark plug 9. The timing of fuel injection is chosen to ensure that suitable momentum is established in the air jet emerging from the transfer means orifice 7, after piston 1 had moved, in order to ensure good entrainment of fuel into air. The zone 15 shows a spinning mass of mixture with small arrows indicating the direction of swirl. The diagram is illustrative only and it is recognised that the swirling stream tube 16 is also surrounded by gas, shown as small dots, and that gas movements are more complicated than the illustration suggest.

Figure 4 illustrates a generalised embodiment of a cylindrical combustion chamber with its axis 19 set at an angle to the axis 18 of cylinder 2. This can offer advantages; it can reduce engine height, improve access to spark plugs and fuel injectors and it can allow shallower helix angles, if needed, when promoting helical swirl flow in the combustion chamber. For example, if the angle between the axis 20 of the transfer orifice means 7 and the axis 18 of cylinder 12 in the plane shown is made ninety degrees, the aperture of the transfer orifice means 7 on the flame plate 5 at the top of cylinder 2 will be circular so minimising the area on the flame plate used for the orifice. Figure 4 is a section taken through and along the axis of symmetry 19 of the combustion chamber, and does not contain the axis 18 of the cylinder. The transfer orifice means 7 can be seen entering the combustion chamber in the vicinity of the near end 8 in a direction pointing a jet of air to rotate around the periphery of the cylindrical combustion chamber 22 in helical swirl flow towards the far end 10. The fuel injection means 11 is shown pointing its spray (not shown) directly at the transfer orifice means and its axis 21 is the same as axis 20. The cone angle of the fuel spray is chosen to match the circular cross section of the transfer orifice means as it enters the combustion chamber, in other words the cross section of the air jet emerging from it, so as to ensure maximum entrainment of fuel into the jet of air.

Figure 5 illustrates a cross-section along line A-A shown in Figure 4 of a similar, but not the same combustion chamber illustrated in Figure 4. No attempt was made to match the angle of entry of the transfer orifice means 7 into the cylinder through the flame plate 5, in both the diagrams. The section is taken across the longitudinal axis of symmetry of the combustion chamber to show the relative orientation of the transfer orifice means 7 and the fuel injection means 11 consistent with the promotion of helical swirl flow, a feature that was not illustrated in the schematic diagrams of Figures 2 and Figure 3.
The tangential entry of the transfer orifice means 7 relative to the circumference 22 is shown in this diagram as well as the proximity of the fuel spray (not shown) emitted by fuel injection means 11 to the exit of the transfer orifice 7. An alternative position for the fuel injection means is also shown 112. In this alternative position some wetting of the wall 22 may take place and entrainment will also rely on evaporation off the wall.

Figures 6 illustrates by way of examples a number of combustion chamber shapes but other geometries can be also used to advantage. The positioning of the spark ignition

means 9 and fuel injection means 11 can be chosen independently of the shape of a combustion chamber 6 to give the best results. Figure 6a shows a cylindrical chamber with hemispherical ends. The rotational velocity near the spark plug 9 will vary with the radius from the axis. The spark plug is located at the centre of the far end where the velocity is perceived to be lowest. Figure 6c shows an offset spark plug and Figures 6d, 6e and 6f illustrate a spark plug situated near or at the periphery of the combustion chamber well within the helical swirl flow. Figure 6e also illustrates a fuel injection means 11 whose axis 21 is at an angle to the axis 20 of the transfer orifice means 7.

The sequence of operations is described by way of an example based on perceptions. Some aspects of the operation of such an engine may differ with rotational speed and load, in particular the timing and duration of fuel injection. Other aspects may vary with the engine design such as the direction of fuel spray and the position of the spark plug. The operation is therefore described at a given engine speed and load and in a four-stroke embodiment as illustrated in Figure 1. The engine performs an exhaust stroke followed by an induction stroke in the usual manner. After the commencement of the compression stroke air is transferred from cylinder 2 into combustion chamber 6 through transfer orifice means 7. When such airflow is established as a jet sufficiently strong to entrain a spray of gasoline aimed directly at it in the opposite direction, the management means 12 energises the fuel injector 11 to spray into the air jet a cone of finely atomised mist. The cone angle is chosen so as to produce a circular cross section of approximately the diameter of the air jet emerging from the transfer orifice which is this example is chosen to be circular in cross section. This helps to ensure that most if not all the fuel is entrained within the air jet. Fuel injection ceases when the required quantity is delivered to meet the desired load condition, but it is set to be discontinued automatically by the management means 12 towards the end of the compression stroke of piston 1 when the air jet entering the combustion chamber is greatly weakened. At higher engine speeds the quantity of fuel injected per unit of time may need to be increased by increasing the pressure of the fuel delivered to the fuel injector or by enlarging the fuel injector's delivery flow area. The minimum fuel line pressure is selected to resist the peak gas pressure in the combustion chamber, following ignition, to ensure that the fuel injector needle remains seated after closure.

The fuel entrained in the air jet is at least partially vaporised and the mixture continues to swirl around the walls of the combustion chamber in helical swirl motion, like a screw thread, moving towards the far end of the combustion chamber. Vaporisation continues when heat is absorbed from the cylindrical walls of the combustion chamber, which had been heated up during the combustion period of the previous cycle. In this way the combustion chamber's wall is cooled cycle after cycle so minimising the need to use external coolant. The compressed mixture also undergoes a reduction of its temperature towards the end of the compression stroke, as a result of vaporisation, and pre ignition dangers are reduced. If turbo-charging is used the need to lower the compression ratio of the engine in order to avoid pre-ignition is also reduced.

After fuel injection ceases further air entering the combustion chamber 6 from cylinder 2 will also be imparted helical swirl motion and compress the mixture that entered earlier. The mixture rotates pressed against the far end 10 of the combustion chamber. There may be some fuel diffusion and mixing in the boundary between the mixture and the air following it but this will not destroy the stratification needed to ensure reliable spark ignition of the fuel in the mixture rotating near the spark plug. The combustion process can be completed within the combustion chamber and the hot gases will move into cylinder 2 through orifice 7 to transfer energy to piston 1 in the usual way.

An indirect combustion chamber according to this invention, which suffers less heat loss to the outside, offers advantages by reducing heat losses after combustion. At the beginning of the expansion stroke of the piston some of the hot gases leave the combustion chamber to enter what is a small volume above the piston equalising the pressures rapidly. Because of its relatively large diameter, by the time the piston sweeps a volume equal to that of the combustion chamber, it will make only a small movement after top dead centre. Even so, during this period, the hot gases lose a great deal of the temperature gained during the combustion process, it is calculated to be about a third. After sweeping a volume twice that of the combustion chamber the reduction is calculated to be about half. However in engines where combustion takes place on the piston's face, where heat readily escapes to the outside, more heat energy will be lost out of the system during the combustion period and immediately afterwards. Using the indirect chamber in this invention the combustion chamber's walls will be cooled by fuel vaporisation during the next cycle and the heat is retained within the internal gases.

The transfer orifice means will produce some additional fluid friction losses but compared with design practice used in the past for diesel engines using indirect combustion chambers, these losses will be much smaller. The spark ignition used in this invention is suitable for volatile fuels, such as gasoline, and the gas velocities needed in the combustion chamber in order to vaporise such fuels are relatively small in comparison with indirect diesel engines. The size of the transfer orifice means is therefore considerably larger than the typical diesel engine's, greatly reducing kinetic energy losses. The transfer of gases, in and out of the combustion chamber, take place under relatively small pressure differences because the volumes on either side of the orifice are able to promote rapid pressure equalisation.

It is perceived that a quantity of fuel delivered to the air jet when it is at its maximum velocity, well after the compression stroke started, will be carried towards the far end of the combustion chamber and reach the spark plug, penetrating through the swirling air or mixture which entered beforehand, due to the higher momentum.

The fuel injection process must be correctly timed and synchronised with the spark event. It is envisaged that combustion is completed rapidly and within the combustion chamber due to the swirling movement of the mixture. Fuel is excluded from the cylinder and therefore cannot be trapped in crevices near the piston rings and valves.

When a vehicle driver uses the engine according to this invention, increasing the duration of fuel injection in terms of crank angle degrees will increase the output torque. If the torque exceeds the resistance to motion the engine and vehicle speed will increase. The time available for fuel injection over the selected number of crankshaft degrees will be reduced. If needed to overcome this, fuel line pressure can be made to increase with engine speed in a predetermined proportion exercised by the management means 12.

This invention is very suitable for use with the two-stroke engine cycle as it only affects the compression stroke of a cycle. Such engines can be either crankcase aspirated or externally aspirated. As no unburnt fuel enters the cylinder at any time the typical disadvantage of blowing fuel into the exhaust which affects many two-stroke engines is removed. The crankcase and crevices around piston rings will also be free from trapped

hydrocarbons. The combustion chamber will automatically contain some products of combustion from the previous cycle, which is beneficial for reducing the amount of Nitrogen Oxides in the exhaust.

CLAIMS

1. An internal combustion engine comprising;

a piston reciprocating in a cylinder;

air inlet means communicating with the cylinder;

exhaust means communicating with the cylinder;

an indirect combustion chamber communicating with the cylinder comprising a near end and a far end in relation to the piston;

transfer orifice means communicating with the cylinder and the combustion chamber at its near end;

spark ignition means communicating with the combustion chamber;

fuel injection means communicating with the combustion chamber;

management means to control the fuel injection and spark ignition processes;

characterised in that the transfer orifice means is adapted to deliver a jet of air into the combustion chamber during the compression stroke of the piston forcing gas movement around the periphery of the combustion chamber in helical swirl motion in the axial direction away from the near end and in that the fuel injection means delivers fuel into the said jet of air to enable a spark ignitable mixture to form in the gas arriving at the spark ignition means.

2. An engine according to claim 1 wherein the said fuel injection means is situated to deliver fuel directly towards the said jet of air along an axis coincident or parallel with the axis of the said jet.

3. An engine according to claim 1, wherein the said fuel injection means is situated to deliver fuel into the said jet of air at an angle to the axis of the said jet.

4. An engine according to any of the preceding claims wherein the said spark ignition means is situated at the said far end of the said combustion chamber.

5. An engine according to any of claims 1 to 3 included, wherein the said spark ignition means is situated at a distance from the said far end of the said combustion chamber.

6. An engine according to any of the preceding claims wherein the said spark ignition means is situated at the said periphery of the said combustion chamber.

7. An engine according to any of the preceding claims wherein the said combustion chamber is symmetrical along its longitudinal axis and with a circular cross section at any point along this axis.

8. An engine according to any of the preceding claims wherein the said combustion chamber is situated with its longitudinal axis not parallel with the direction of the axis of the engine's said cylinder.

9. An engine according to any of the preceding claims operating on the four-stroke cycle.

10. An engine according to any of claims 1 to 8 included, operating on the two-stroke cycle.

11. An engine according to any of the preceding claims wherein air induction into the cylinder is not restricted in order to operate at part load.

ABSTRACT

INTERNAL COMBUSTION ENGINE.

A lean-burn engine suitable for gasoline and transport. It uses an indirect combustion chamber and a transfer orifice aligned to produce a jet of air moving in helical swirl flow around the chamber during the compression stroke. Fuel injection into the combustion chamber is timed to deliver fuel during the compression stroke aimed directly into the jet of air as it enters the combustion chamber ensuring that a spark ignitable mixture is formed when the fuel and air are blended during motion. After fuel delivery ceases air continues to enter the chamber but does not fully mix with the mixture formed earlier because of the stratifying effect produced by helical swirl. A spark plug is situated where the rotating mixture reaches at the end of its axial travel. Spark ignition and combustion are possible at part load even when a proportion of the chamber contains spinning air without any fuel.

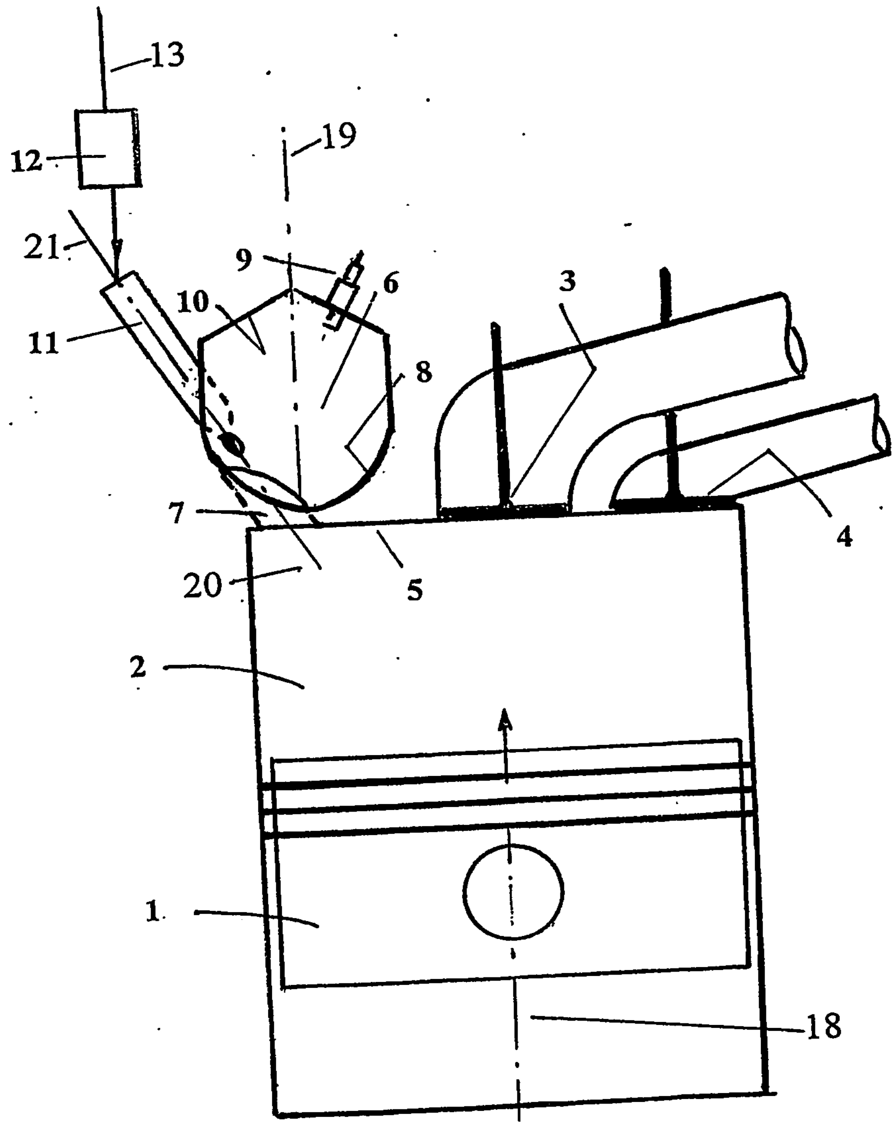

FIG 1

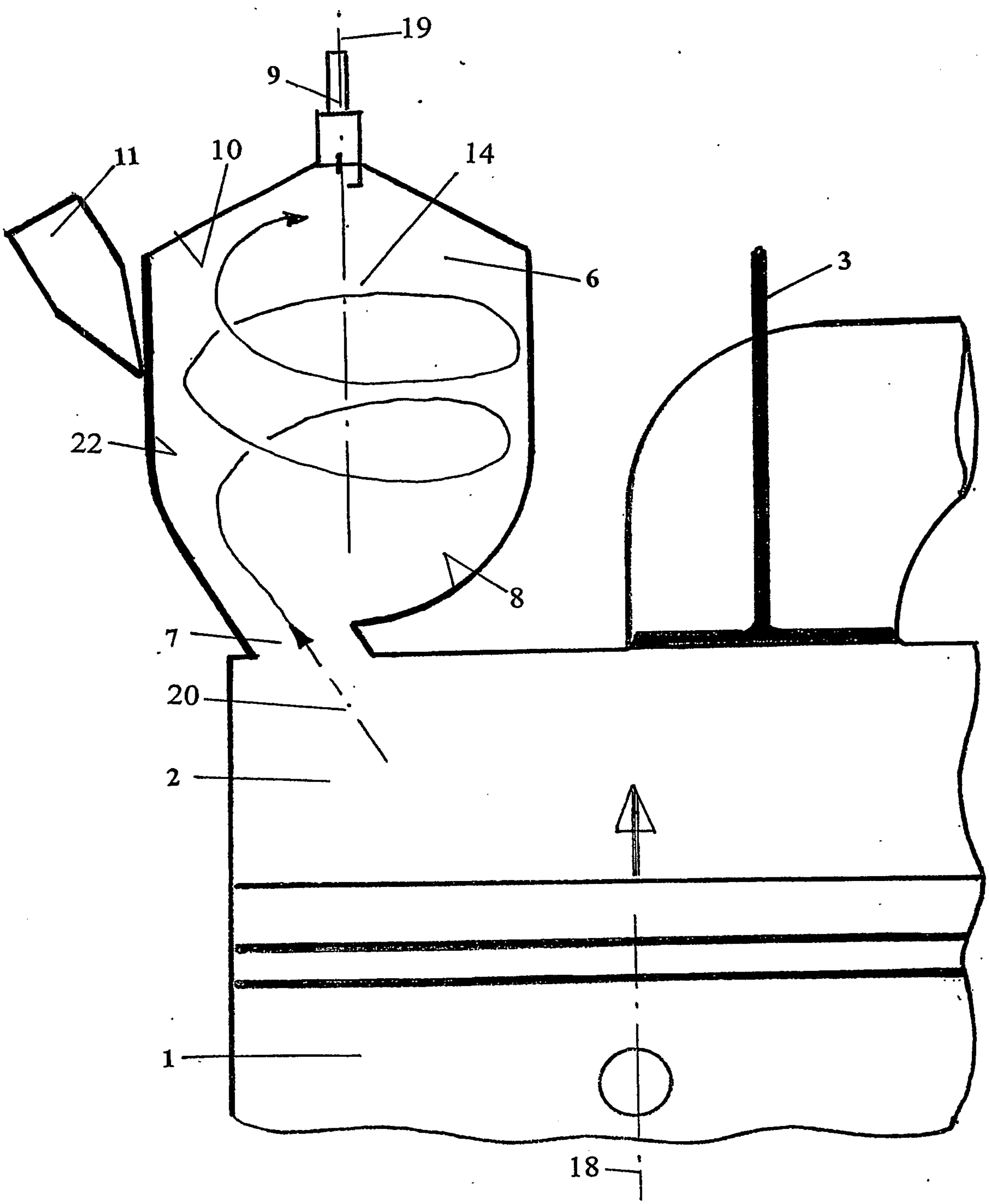

FIG 2

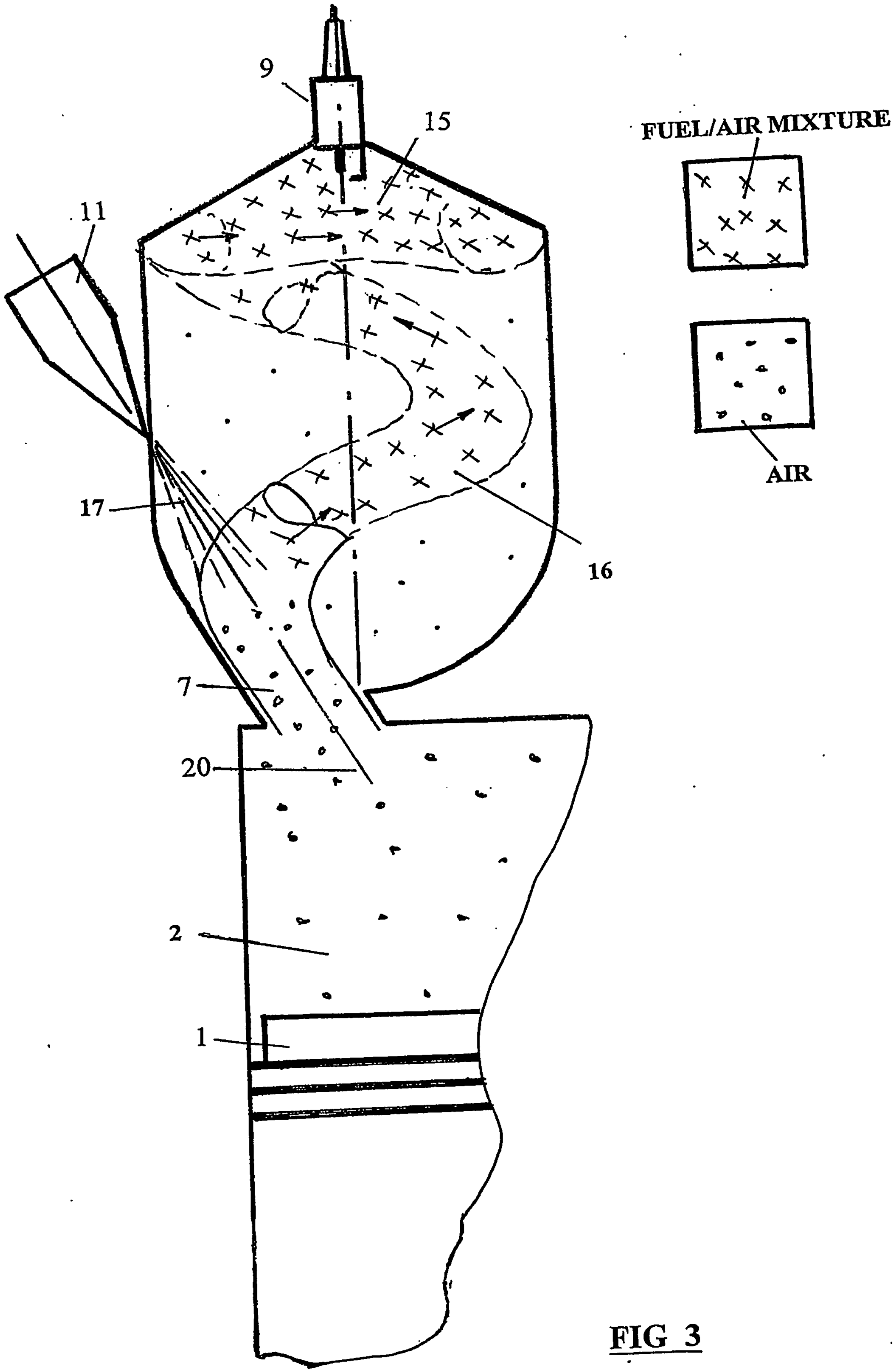

FIG 3

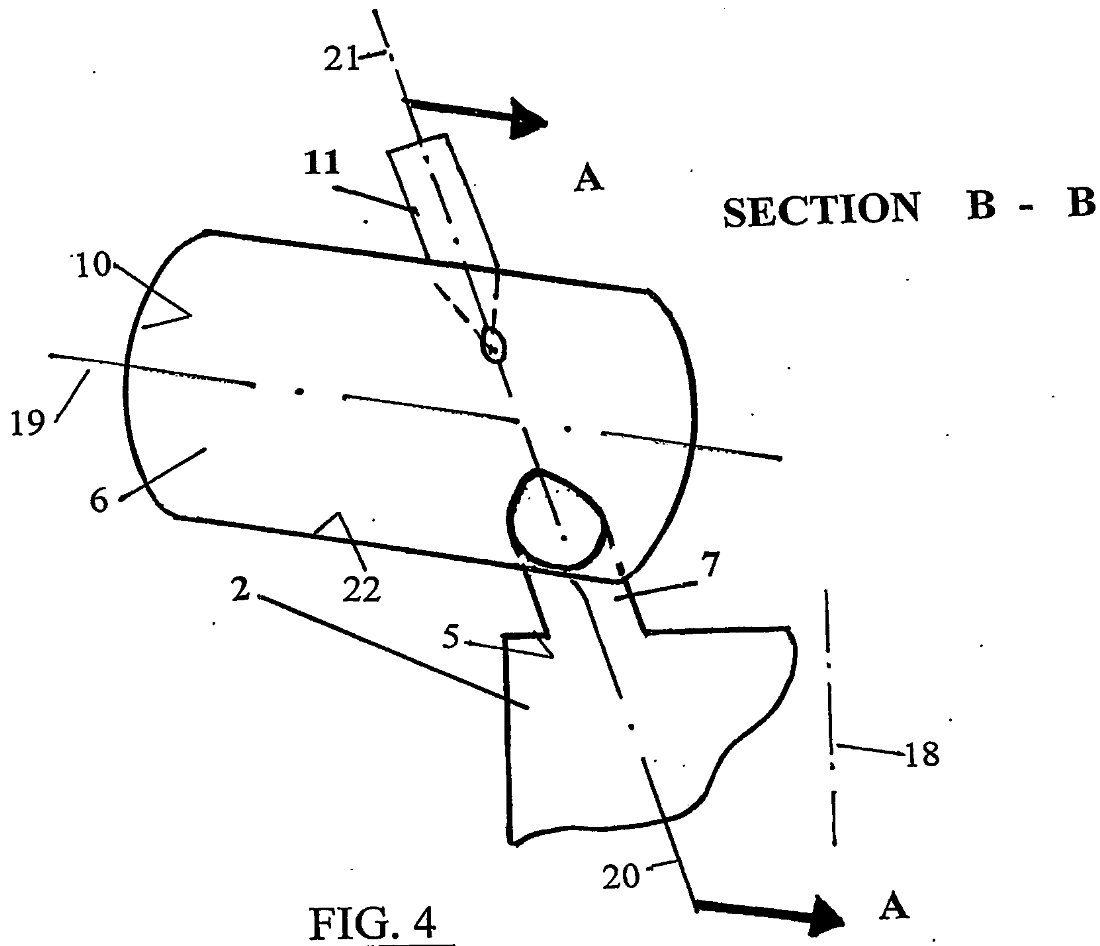

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FIG. 4

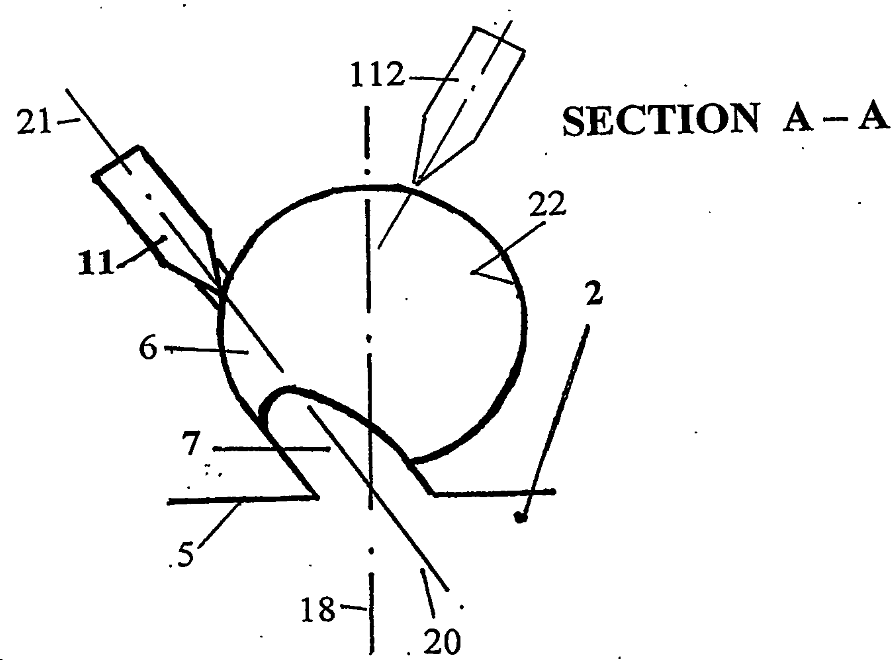

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FIG. 5

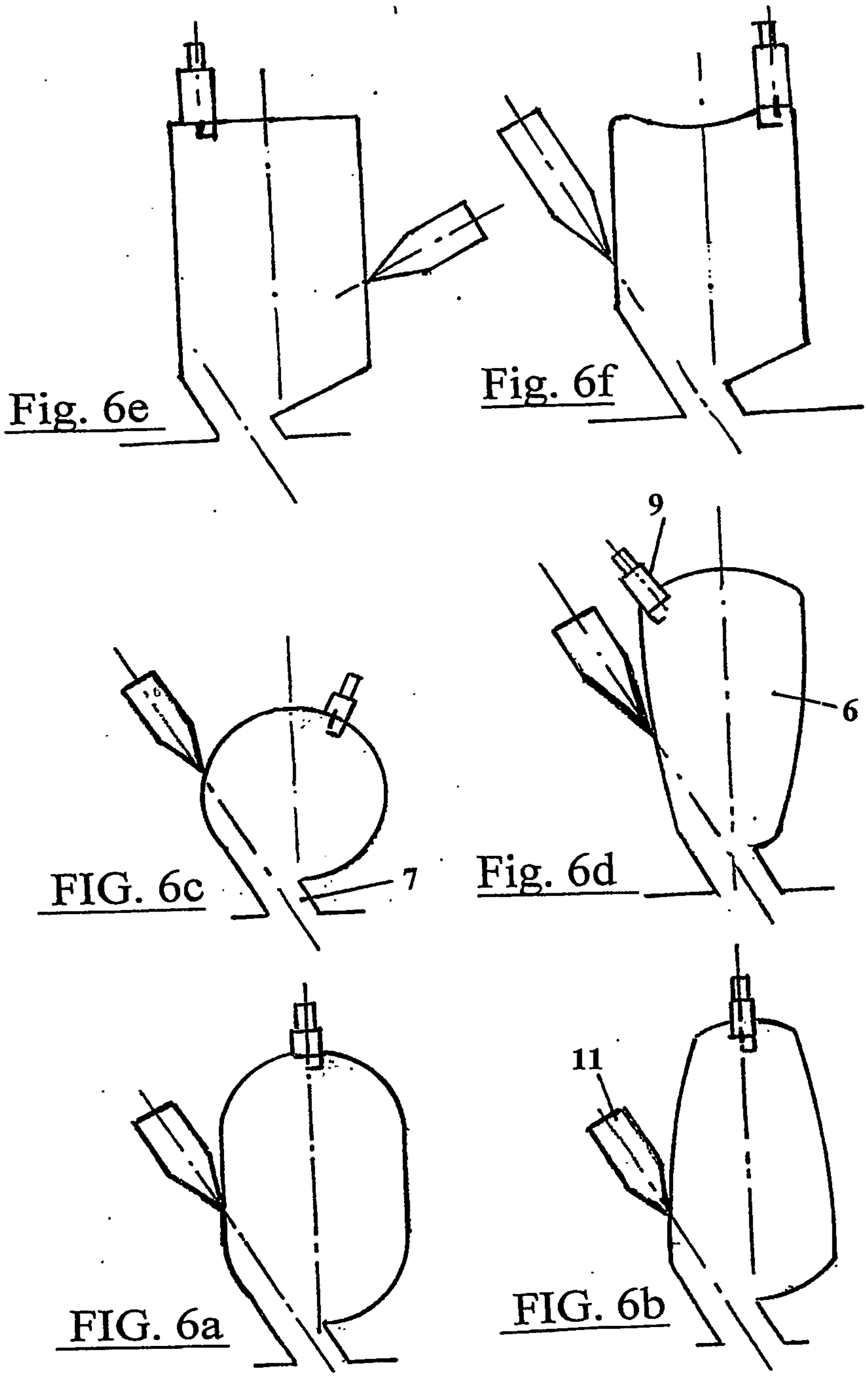

FIG. 6